AN ELECTROMYOGRAPHIC STUDY OF THE EMPHATIC CONSONANTS
IN STANDARD JORDANIAN ARABIC

Fukuko Kuriyagawa, Masayuki Sawashima,
Seiji Niimi and Hajime Hirose

1. Introduction

Previous studies have mostly reported that the frequency of the second formant of vowels in the vicinity of emphatic consonants decreases in sequences of phonemes containing the emphatic consonants in Arabic [1-4].   As to the articulatory gestures of the emphatic consonants, one study mentions that the hyoglossus, genioglossus and digastricus muscles are mostly involved in the production of the emphatic consonants based on observation by X-ray films of the change in the relative positions of the cervical vertebrae and the root of the tongue, epiglottis, hyoid bone or pharynx [5].

The present study aims at comprehension of some production characteristics of the emphatic consonants in standard Jordanian Arabic by means of electromyography(EMG) [6].   The activities of the posterior part of the genioglossus(GGP) and the geniohyoid(GH), which take part in the gesture of the tongue for articulation, were observed by EMG and compared for the articulation of emphatic consonants and non-emphatic consonants. The activity of the orbicularis oris(OO) was also measured to observe the articulatory gesture of the lips.

2. Experimental procedures

Three pairs of test words consisting of CVC mono-syllables, the syllable-initial of which contained emphatic consonants or non-emphatic consonants for comparison, were prepared for the experiment.   Each   test   word   was   uttered in the frame /ha:x̌a:——/ (This is ——).

The subject was an adult, male native speaker of the standard Jordanian dialect of modern Arabic and uttered the test sentences ten times each. EMG signals from the GGP, GH and OO using hooked-wire electrodes, were recorded with speech signals simultaneously by multi-channel method after high-pass filtering at 100 Hz. After full-wave rectification, the action potentials were integrated over a 10 msec time window and fed into a computer at a sampling rate of 100 Hz. The patterns of the average time curves of the EMG activity relative to the acoustic signals for the 10 utterances were obtained through smoothing after ensemble-averaging from 0.4 sec before and after the line-up point, which was set at the offset of the word-final vowel in the carrier sentence with respect to the speech envelope.

Table 1. Test word

<u>non-emphatic</u>   <u>emphatic</u>

/si:b/ 'let go' (imperative)   /ʂi;b/ 'hit a target' (imperative)

/si:ħ/ 'travel' (imperative)   /ʂi:ħ/ 'cry' (imperative)

/tu:b/ 'repeat' (imperative)   /ʈu:b/ 'bricks' (noun)

3. Results and discussion

Figs. 1, 2 and 3 give the results of the EMG measurement and the activities of OO, GH and GGP and the speech envelope are shown from top to bottom. Only the test words are discussed here, even though differences in activity were found during the utterance of the carrier sentence depending on whether there was an emphatic consonant or non-emphatic consonant in the test words. It became clear from the speech envelope that the duration of /ʂ/ was longer than that of /s/. It can be concluded that to differentiate /ʂ/ from /s/ a longer duration is necessary.

Duration of consonants

Consonant	Average SD(msec)	Consonant	Average SD(msec)
(1) /s/ in /si:b/	154 7	(1') /ʂ/ in /ʂi:b/	170 12
(2) /s/ in /si:ħ/	146 9	(2') /ʂ/ in /ʂi:ħ/	166 7
(3) /t/ in /tu:b/	136 12	(3') /ʈ/ in /ʈu:b/	131 12

3.1 GGP

3.1.1 Comparison of /si:b/ and /ʂi:b/ (Fig. 1)

The activity of the GGP beginning about 0.1 sec before ·the onset of the articulation of /s/ in /si:b/ seems to correspond to the articulation of /s/. The highest peak found about 0.1 sec after the onset of the articulation of /s/ corresponds to the articulation of /i/. On the other hand, no activity corresponding to /ʂ/ was observed in /ʂi:b/, and the activity found abruptly from 0.06 sec after the onset of /ʂ/ was considered to correspond to /i/. The degree of this activity is more remarkable in /ʂi:b/ than in /si:b/.

3.1.2 Comparison of /si:ħ/ and /ʂi:ħ/ (Fig. 2)

The activity of the GGP beginning about 0.1 sec before the onset of the articulation of /s/ in /si:ħ/ is considered as corresponding to /s/. The highest peak found about 0.08 sec after the onset of the articulation of /s/ corresponds to the

articulation of /i/. Then, the activity decreased abruptly and was sustained slightly until 0.45 sec after the onset of the articulation of /s/. On the other hand, activity corresponding to /s̶/ was not observed in /s̶i:ħ/, while a sharp activity corresponding to /i/ was found from 0.06 sec after the onset of the articulation of /s̶/. The degree of activity corresponding to the articulation of /i/ was apparently greater for /s̶i:ħ/ than /si:ħ/. Activity corresponding to /ħ/ was hardly found in either /si:ħ/ or /s̶i:ħ/.

3.1.3 Comparison of /tu:b/ and /ţu:b/ (Fig. 3)

The activity of the GGP was not observed after the onset of the closure of either /t/ or /ţ/. The peak observed just before the line-up point is considered as activity corresponding to the articulation of /t/, while no activity corresponding to the articulation of /ţ/ was observed.

3.1.4 Summary of the activities of the GGP

The activity of the GGP observed just before the onset of both of the non-emphatic consonants /s/ and /t/ in the word-initial position of the test words was not observed in the test words containing emphatic consonants /s̶/, /ţ/ word-initialiy. The function of the GGP is considered to draw the tongue body forward in the oral cavity, and the activity of the GGP is suppressed when the retraction of the tongue occurs and the root of tongue is brought back toward the wall of the pharynx. This is also demonstrated by the fact that the activity of the GGP in the articulation of /ħ/ mostly disappeared, which agrees with the suggestion of Giannini that the articulation of emphatic consonants may be pharyngealized[5]. On the other hand, the activity of the GGP for the following vowel /i/ after the articulation of the emphatic consonant /s̶/ increased more than after the non-emphatic consonant /s/. It may be supposed that a greater activity of the GGP is needed to draw the tongue, which is retracted toward the wall of·pharynx because of the production of the emphatic consonants, forward again in the oral cavity in order to realize the articulation of the following /i/. However, it is necessary to discuss vowels in relation to the activities of the other muscles involved in the gestures of the tongue in speech production.

3.2 GH

3.2.1 Comparison of /si:b/ and /s̶i:b/ (Fig.1)

The activities of the GH corresponding to the articulation of /i/ increased from about 0.05 sec before the onset of the articulation of /s/ and /s̶/. The highest peaks for /si:b/ and for /s̶i:b/ were found 0.09 sec after the onset of /s/, and 0.1 sec after the onset of /s̶/, respectively. The activity was greater in /s̶i:b/ than /si:b/.

3.2.2 Comparison of /siːħ/ and /ʃiːħ/ (Fig.2)

In the activity of the GH in /siːħ/, a peak corresponding to /i/ was observed 0.06 sec after the onset of /s/. The activity then decreased, but quick reactivation occurred to reach a maxmum 0.25 sec after the onset of /s/. This reactivation is considered to correspond to /ħ/. On the other hand, in /ʃiːħ/ a peak corresponding to /i/ was found 0.1 sec after the onset of /ʃ/. The activity then suddenly decreased but again began to increase to reach a peak corresponding to /ħ/ 0.3 sec after the onset of /ʃ/. This peak was smaller than that corresponding to the /ħ/ in /siːħ/.

3.2.3 Comparison of /tuːb/ and /ʈuːb/ (fig.3)

A slack activity in the GH corresponding to the articulation of /u/ was observed from just before the line-up point in /tuːb/. In /ʈuːb/, the activity which is also regarded as corresponding to /u/, increasing about 0.1 sec before the onset of the closure for /ʈ/, was sustained for about 0.3 sec and then decreased gradually.

3.2.4 Summary of the activities of GH

No difference in the activity of the GH was found between the production of the emphatic consonants /ʃ/, /ʈ/, and the non-emphatic consonants /s/, /t/. The activity of the GH for /u/ and /i/ increases in cases where these vowels follow the emphatic consonants /ʃ/ and /ʈ/. Concerning these vowels, discussion is necessary in relation to the activities of the other muscles involved in the gestures of the tongue in speech production.

3.3 OO

3.3.1 Comparison of /siːb/ and /ʃiːb/ (Fig.1)

Slack activities were observed after the onset of word-finals /s/ and /ʃ/ in both /siːb/ and /ʃiːb/, and the maxmum peaks were observed 0.24 sec after the onset of /s/ in /siːb/ and 0.27 sec after the onset of /ʃ/ in /ʃiːb/. These peaks are considered to correspond to the articulation of /b/. These activities decreased abruptly to cease 0.5 sec after the onset of/s/ in /siːb/, and 0.62 sec after the onset of /ʃ/ in /ʃiːb/. The activity corresponding to /b/ was less in /ʃiːb/ than /siːb/.

3.3.2 Comparison of /siːħ/ and /ʃiːħ/ (Fig.2)

No remarkable activites were observed, besides the slight increase in activity after the onset of the test words. In /siːħ/, the activity began 0.48 sec before the onset of /s/ to reach an even peak at 0.2 sec before the onset of /s/. Then, the activity increased slightly at the onset of /s/ but became even 0.14 sec after the onset of /s/. In /ʃiːħ/, the activity began 0.48 sec before the onset of /ʃ/, and a slight increase in

activity was found about 0.2 sec, but it was smaller than the even peak of /siːħ/. It was sustained and increased for 0.2 sec and then became negligible.

3.3.3 Comparison of /tuːb/ and /ƭuːb/ (Fig.3)

Steep activities occurred about 0.08 sec before the onset of the closure for /t/ and /ƭ/ in the word-initial position in both /tuːb/ and /ƭuːb/. Activities in a couple of the first and the second peaks corresponding to the production of /u/ were observed about 0.02 sec and 0.08 sec after the onsets of /t/ and /ƭ/, respectively. Then the activities decreased, and again reactivation occurred to reach the third peak corresponding to /b/ 0.28 sec after the onset of the closure for /t/ and /ƭ/. In /tuːb/, the activity decreased suddenly to cease 0.36 sec after the onset of the closure for /t/ compared with the speech envelope. In /ƭuːb/ remarkable activity was observed after the third peak and sustained 0.32 sec longer than in /tuːb/.

3.3.4 Summary of the activities of the OO

The activity of the OO was remarkable in the production of /u/ and the /b/ which followed /u/. The emphatic consonant /ƭ/ increased the activity of the OO corresponding to both the /u/ and /b/ which followed /ƭ/ and lengthened the duration of this activity. On the other hand, the activity decreased in the /b/ which followed the emphatic consonant /ṣ/ compared to the non-emphatic consonant /s/. Consequently, the influence of emphatic consonants on the OO is not consistent, but depends on the phonetic environment.

Acknowledgements

References

1) Obrecht, Dean H. (1968); Effects of the second formant on the perception of velarization consonants in Arabic, Mouton, The Hague.
2) Al-Ani, Salman H. (1970); Arabic phonology, An acoustical and physiological investigation, Mouton, The Hague.
3) Kuriyagawa, F. (1983); Tables of Arabic words for experimental phonetics, Ann. Bull. RILP, 17, 1-12.
4) Kuriyagawa, F. (1984); The features of /k/ and /q/ in Cairo standard Arabic, Ann. Bull. RILP, 18, 65-73.
5) Giannini, A. and M. Pettorino (1982); The Emphatic Consonants in Arabic, SLR 4, Instituto Universitario Orientale Seminario di Studi dell'Europa Orientale Laboratorio di Fonetica Sperimentale, Napoli, p27.

6) Hirose, H. (1977); "Electromyography of the Larynx and Other Speech Organs", in Dynamic Aspects of Speech Production (Eds. Sawashima, M. and F. S. Cooper), University of Tokyo Press, Tokyo, 49-67.
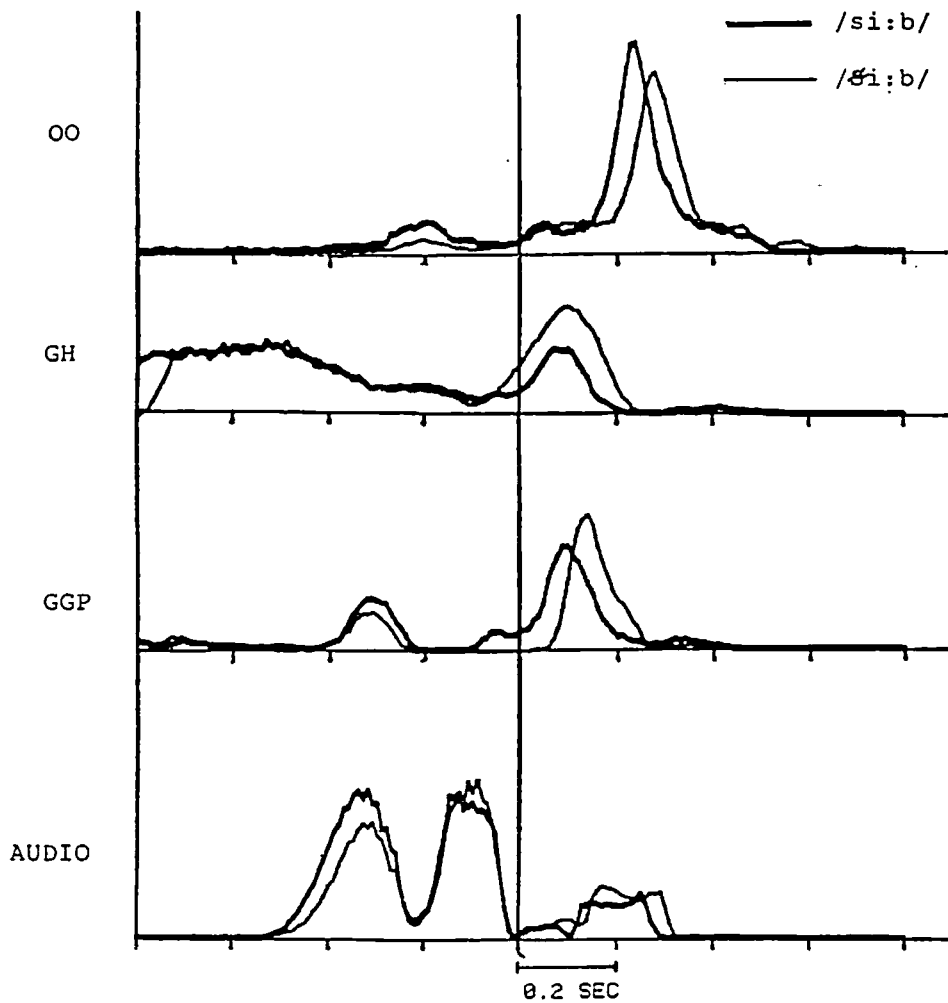
Fig.1 Averaged EMG curves of the orbicularis oris(OO), the genio-
hyoid(GH) and the posterior part of the genioglossus(GGP) for the
utterances /ha:ɕa:si:b/(thick line) and /ha:ɕa:ɕi:b/(thin line).
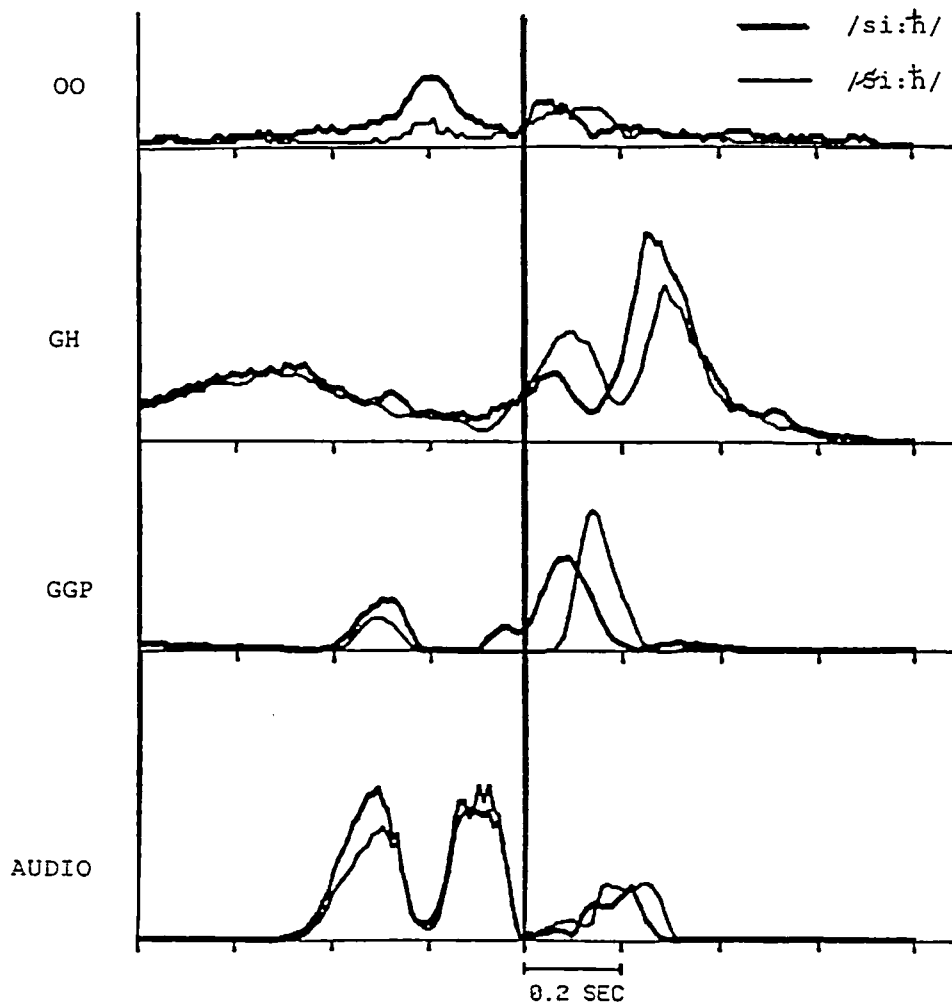The bottom curves are averaged audio-envelopes(AUDIO).

Fig.2 Averaged EMG curves of the OO, GH and GGP for the utterances /ha:ꭓa:si:ħ/ (thick line) and /ha:ꭓa:ɕi:ħ/ (thin line).
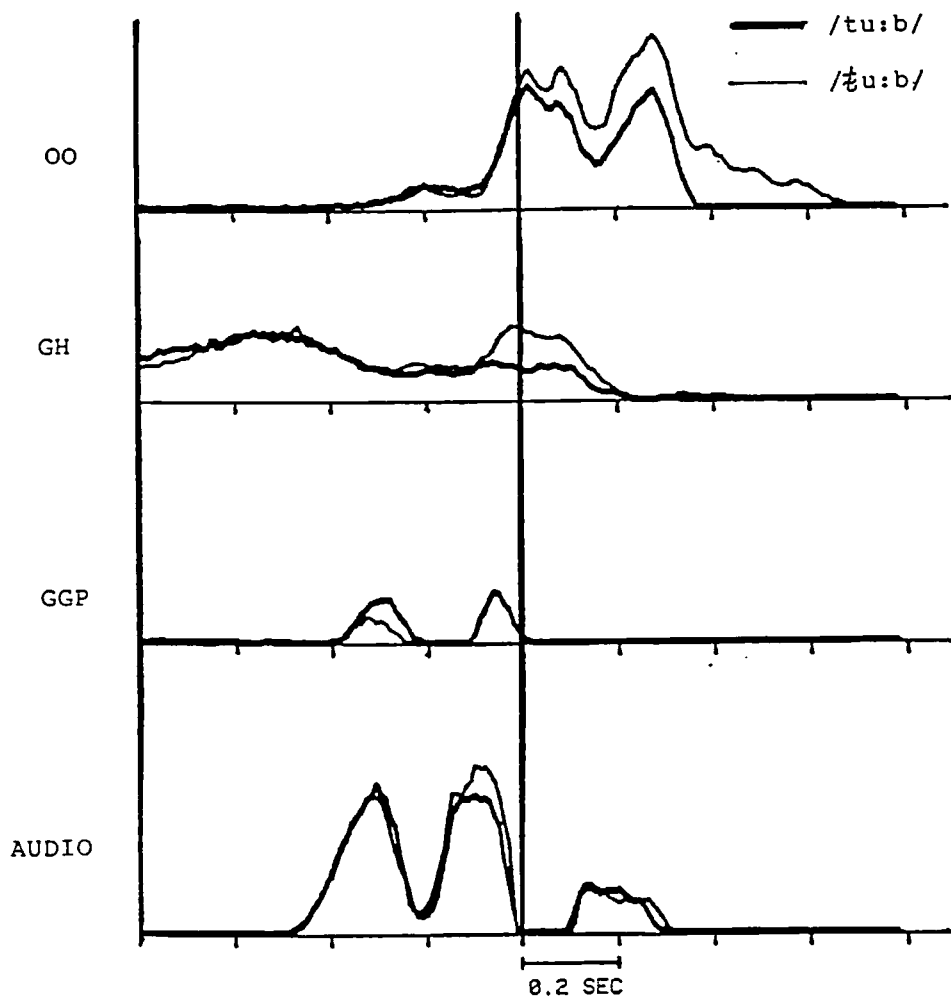
Fig.3 Averaged EMG curves of the OO, GH and GGP for the utterances
/ha:ɤa:tu:b/(thick line) and /ha:ɟa:ʨu:b/(thin line).